Electronic Supplementary Material (ESI) for Lab on a Chip

Supplementary Information For

Microfluidic oscillators with widely tunable periods

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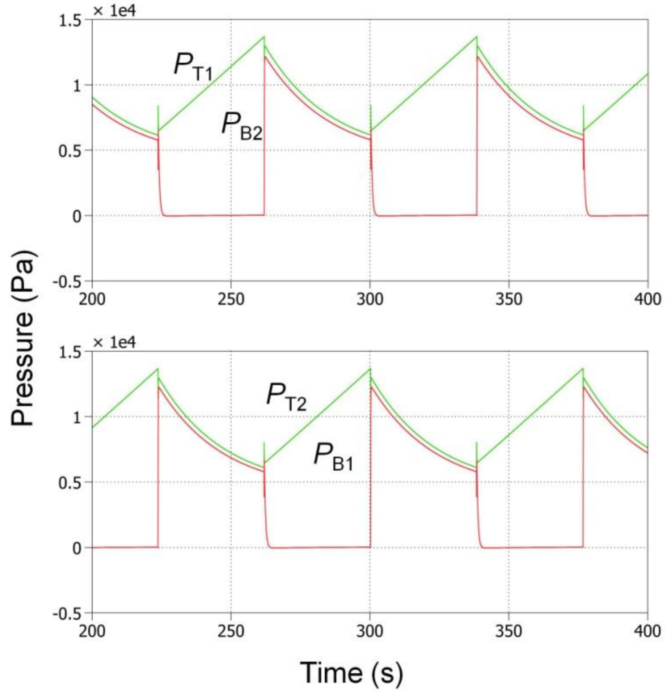
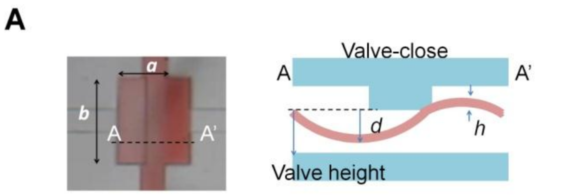


Fig. S1 Top and bottom pressure of valves 1 and 2. The values were obtained from a theoretical model. The difference between P_{T1} and P_{B2} or between P_{T2} and P_{B1} is ~5% in the valve-open state. Thus, we can approximate P_{B2} as P_{T1} and P_{B1} as P_{T2} to measure threshold pressure. C_i, C_e, $P_{th\text{-}close}$, $P_{th\text{-}close}$, and Q_i are 1.8×10^{-13} m^5 N^{-1}, 8.5×10^{-13} m^5 N^{-1} , -1 kPa, 7.9 kPa, and 10 μL min^{-1}, respectively.



	C_i (m^5 N^{-1})			
	1.67×10^{-11}	2.59×10^{-13}	1.78×10^{-14}	2.89×10^{-15}
a (mm)	1.04	0.5	0.3	0.3
b (mm)	1.8	1	0.8	0.8
h (µm)	6	6	6	11

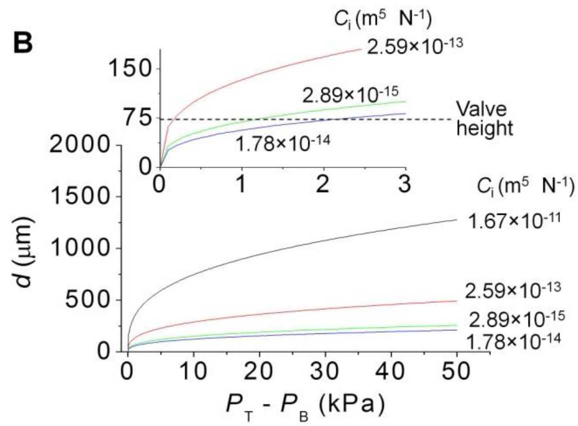


Fig. S2. (A) Valve dimensions used for estimating C_i. *a* is a measure of valve length, *b* is valve width, and *h* is membrane thickness. C_i of each valve is calculated by $C_i = \frac{\partial V}{\partial P} = \frac{a^4}{4\pi^4 D}\frac{ab}{3+3n^4+2n^2}$, where *D* is $\frac{Eh^3}{12(1-\nu^2)}$, and *V* and *P* are the volume and pressure, respectively (ref. S1). C_i is estimated under the condition that the valve's membrane did not touch the valve's bottom floor. (B) Theoretical membrane deflection by $P_T - P_B$ change. The graph shows how the small heights of the valves limit the extent of membrane deflection, *d*, thus reducing the effective C_i. When the valve is closed, its membrane deflects downward as $P_T - P_B$ increases. This deflection continues until $P_T - P_B > P_{th\text{-}open}$. $P_{th\text{-}open}$s were measured between 9 and 40 kPa depending on the valve type. At $P_T - P_B$ = 3 kPa, which is < $P_{th\text{-}open}$ (i.e. close valve state), even the membrane of the smallest valve having $C_i = 1.78\times10^{-14}$ m^5 N^{-1} deflects more than the valve height of 75 µm. In other words, the valve's membrane can touch the valve's bottom floor before the valve opens. This contact greatly decreases the effective C_i value. Thus, to make C_i constantly larger than C_e, for example a valve having a constantly large $C_i = 1.67\times10^{-11}$ m^5 N^{-1} was prepared by making the valve height ~ 2 mm so the membrane does not touch the bottom. It should be noted that the contact does not affect the oscillation of the small size valves (the first three valves in the table of Fig. S2A) having 75 µm valve height, because the contact rather increases C_e/C_i through the decrease of effective C_i and thus the condition of C_e/C_i >1 is kept. *d* is calculated from $d = ((P_T - P_B)\frac{a^4}{JEh})^{1/3}$, where $J = \frac{\pi^6}{32(1-\nu^2)}\left[\frac{9+2n^2+9n^4}{256} + \frac{\{4+n+n^2+4n^3-3\nu n(n+1)\}^2}{2\{81\pi^2(1+n^2)+128(1+\nu)n-9\pi^2\nu(1+n^2)\}}\right]^{1/3}$ and *n* is *a/b* (ref. S2). *E* and ν are 3.5 MPa and 0.5, respectively.

References

(S1) A. C. Ugural in Stresses in plates and shells (McGraw-Hill, Boston, 1981), pp. 90-92.

(S2) O. Tabata, K . Kawahata, S. Sugiyama and Igarashi I, *Sens. Actuators* 1989, **20**, 135–141.